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Evidence of Lake Whitefish Spawning in the Detroit River: Implications for Habitat and Population Recovery

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ABSTRACT. *Historic reports imply that the lower Detroit River was once a prolific spawning area for lake whitefish* (Coregonus clupeaformis) *prior to the construction of the Livingstone shipping channel in 1911. Large numbers of lake whitefish migrated into the river in fall where they spawned on expansive limestone bedrock and gravel bars. Lake whitefish were harvested in the river during this time by commercial fisheries and for fish culture operations. The last reported landing of lake whitefish from the Detroit River was in 1925. Loss of suitable spawning habitat during the construction of the shipping channels as well as the effects of over-fishing, sea lamprey* (Petromyzon marinus) *predation, loss of riparian wetlands, and other perturbations to riverine habitat are associated with the disappearance of lake whitefish spawning runs. Because lake whitefish are recovering in Lake Erie with substantial spawning occurring in the western basin, we suspected they may once again be using the Detroit River to spawn. We sampled in the Detroit River for lake whitefish adults and eggs in late fall of 2005 and for lake whitefish eggs and fish larvae in 2006 to assess the extent of reproduction in the river. A spawning-ready male lake whitefish was collected in gillnets and several dozen viable lake whitefish eggs were collected with a pump in the Detroit River in November and December 2005. No lake whitefish eggs were found at lower river sites in March of 2006, but viable lake whitefish eggs were found at Belle Isle in the upper river in early April. Several hundred lake whitefish larvae were collected in the river during March through early May 2006. Peak larval densities (30 fish/1,000 m^3 of water) were observed during the week of 3 April. Because high numbers of lake whitefish larvae were collected from mid- and downstream sample sites in the river, we believe that production of lake whitefish in the Detroit River may be a substantial contribution to the lake whitefish population in Lake Erie.*

INDEX WORDS: *Lake whitefish, habitat, spawning, Detroit River, Lake Erie, restoration.*

INTRODUCTION

Lake whitefish (*Coregonus clupeaformis*) and cisco (*Coregonus artedii*) historically supported vigorous commercial fisheries in the Detroit River. These fisheries also served as a source of gametes for fish culture operations in the late 19th and early 20th centuries (Todd 1986). In 1872, Detroit ranked second only to Chicago for handling over 2.5 mil-

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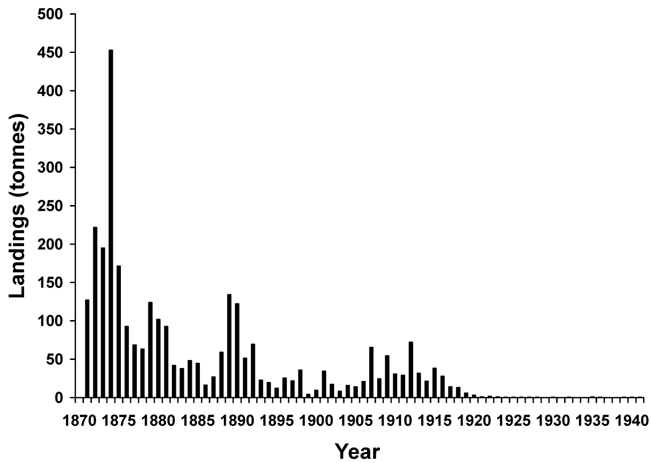

FIG. 1. Landings of lake whitefish (tonnes) in Lake St. Clair and connecting waters, 1872–1939 (Baldwin* et al. *2006).

lion pounds of fresh fish (about 11% of the entire Great Lakes fishery) that included mostly lake whitefish and cisco (Milner 1874). Much of the fresh fish market in Detroit was taken from spawning runs of lake whitefish and lake herring that ascended the river each fall. These fisheries were conducted between the mouth of the Detroit River and the city of Detroit (Hubbard 1887) and were among the most lucrative in the Great Lakes (Milner 1874). Timing of these historic runs ranged from mid-October through mid-December and eggs typically hatched in late March (Goodyear *et al.* 1982, Trautman 1957). Figure 1 depicts the magnitude of landings of lake whitefish from Lake St. Clair and connecting waters including the Detroit River. We used the statistics for these waters because few reliable statistics are available for the Detroit River alone from this time period. Landings of lake whitefish in Lake St. Clair and connecting waters was at its highest in the mid 1870s, peaking at 450 tonnes in 1874. Landings fluctuated between 16 and 140 tonnes from 1875 through 1892, averaging about 50 tonnes per year. Landings were considerably lower from the late 1890s through 1920 when commercial fishing for lake whitefish in this region had all but ceased (Baldwin *et al.* 2006, Ford 1943). Spawning runs of lake whitefish into the Detroit River had almost disappeared by the early 1900s due to overfishing and habitat degradation (Manny and Kenaga 1991, Trautman 1957) and stocks in western Lake Erie were beginning to decline by 1914 (Downing 1923).

The construction of deep shipping channels to accommodate large inter-lake vessel traffic may have had the greatest detriment to lake whitefish runs in the Detroit River. To increase shipping traffic in the Detroit River, the U.S. government began large-scale engineering works in 1905 to increase the size of the shipping channels (Larson 1995). These channels were constructed in areas thought to be used as spawning grounds for lake whitefish, cisco, as well as other fish species (Smith 1917). Following this, large catches of whitefish in Lake Erie from Monroe Pier, Michigan and along the Canadian shore at the mouth of the Detroit River were reported in 1911, but few fish ascended the river in comparison with the enormous runs of previous years (Smith 1915, Bowers 1913). The last lake whitefish landed from the Detroit River was likely caught in 1925 from Ontario waters (Ford 1943).

Lake whitefish are a valuable component of Great Lakes fisheries and are recognized as an indicator of ecosystem health and integral component of Great Lakes food webs (Ryan *et al.* 2003). Landings of lake whitefish from Lake Erie averaged about 1,000 tonnes up until 1940 when effort increased and the "fishing up" of stocks increased landings to over 3,000 tonnes by the early 1950s (Fig. 2). After this peak, landings declined precipitously and no lake whitefish were harvested from Lake Erie between 1960 and the late 1980s. The abundance of lake whitefish in Lake Erie was severely reduced by fishing, habitat degradation, sea lamprey predation (*Petromyzon marinus*), and effects of competition and predation of rainbow smelt (*Osmerus mordax*) prior to 1960 (Hartman 1972, Lawler 1965, Trautman 1957), but the persistence of remnant self-sustaining stocks in Lakes Huron and Erie coupled with habitat rehabilitation efforts allowed the Lake Erie lake whitefish population to recover in the 1980s. This recovery coincided with the recovery of other Lake Erie species such as walleye (*Sander vitreus*), white bass (*Morone chrysops*), and yellow perch (*Perca flavescens*) (Cook *et al.* 2005, Ryan *et al.* 2003). Lake-wide catches of lake whitefish by commercial fishers in Lake Erie have averaged about 250 tonnes per year since 1990 (Fig. 2; Cook *et al.* 2005, Markham *et al.* 2005). In 2000, lake whitefish was the most harvested fish in both U.S. and Canadian waters of the Great Lakes with approximately 10,000 tonnes landed having a dockside value exceeding $US 18 million (Kinnunen 2003). Lake Erie contributed about 6.5% of the total lake whitefish harvest in 2000 (Markham *et al.* 2005, Kinnunen 2003).

Reefs and shoals in the Detroit River and western

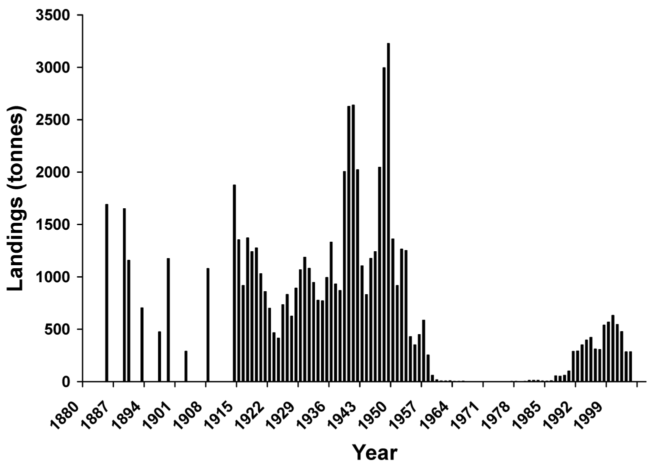

FIG. 2. Landings of lake whitefish in Lake Erie, 1885–2005 (Markham **et al.** *2005, Baldwin* **et al.** *2006).*

Lake Erie are known historic spawning grounds for lake whitefish (Goodyear *et al.* 1982, Downing 1923, Smith 1917) and lake whitefish are presently known to spawn on mid-lake reefs in western Lake Erie (Roseman 1997, 2000). Evidence of over-winter lake whitefish egg survival on western Lake Erie reefs was discovered during assessments of walleye spawning periodicity in late March and April from 1994 to 1999 (Roseman 1997, 2000). Further, pelagic lake whitefish larvae were collected then in large numbers throughout the western basin in ichthyoplankton samples (Roseman 1997, 2000) and in the central basin from 2000 to 2002 (Savino *et al.* 2003), although the source of these larvae is unknown. This information demonstrates that the western basin of Lake Erie contains important spawning and nursery habitat for lake whitefish, even though the extent of its use and the mechanisms regulating recruitment of these fish are currently not understood due to a lack of investigation.

Throughout their range, lake whitefish spawn in late fall as early as mid-September through early December, depending on latitude and water temperature. Lawler (1965) found that Lake Erie lake whitefish did not begin spawning until water temperatures fell below 8.0°C. Lake whitefish are broadcast spawners, casting eggs over shallow (< 8 m water depth) reefs and nearshore areas having hard or stony substrates but may also use sand (Freeberg *et al.* 1990, Taylor *et al.* 1987, Scott and Crossman 1973). Fecundity varies with female size and condition. The number of eggs per pound of fish was reported as 16,100 for lake whitefish collected in eastern Lake Erie in the 1950s (Lawler 1961). Eggs incubate over winter and hatch from March through May. Incubating eggs are subject to mortality induced by predation, removal by currents, storm events, and increases in water temperature (Freeberg *et al.* 1990, Taylor *et al.* 1987). Normal embryological development occurs at a thermal optimum between 3.2 and 8.1°C (Brooke 1975). Incubation at higher temperature can result in mortality and abnormal development (Brooke 1975, Price 1960). Upon hatching, fry are pelagic and dependant on water currents for dispersal to nursery areas (Freeberg *et al.* 1990, Scott and Crossman 1973).

Recently, scientists at the United States Geological Survey (USGS) Great Lakes Science Center discovered viable walleye eggs in the Detroit River near Belle Island suggesting that successful walleye reproduction occurs there (Manny *et al.* 2007). Fishery scientists who manage Detroit River fisheries suspect walleye spawning is widespread in the river (Personal communication; Gary Towns, Michigan Dept. Natural Resources, Southfield, MI, February 2006). Because lake whitefish spawn on habitat similar to that used by walleye in other waters (e.g., western Lake Erie reefs; Roseman 1997), we hypothesize that lake whitefish also spawn on reefs used by spawning walleye in the Detroit River. The purpose of this study was to evaluate the recovery of lake whitefish in the Detroit River. To this end, we determined the extent of lake whitefish spawning in the Detroit River and the degree of reproductive success based on egg survival and hatching.

METHODS

The 51-kilometer long Detroit River is an international waterway linking Lake St. Clair and the upper Great Lakes to Lake Erie (Figs. 3 and 4). Mean daily discharge of the river is approximately 5,300 m^3/sec (Derecki 1984). The river contains numerous islands as well as a deep (>10 m) shipping channel that runs the length of the river. The composition and arrangement of bottom substrates varies throughout the river but large expanses of exposed rock are present, especially near islands (Bolsenga and Herdendorf 1993). The Detroit River area is home to about 10% of the human population living in the Great Lakes basin and hosts the two most important border crossings between Canada and the United States and one of the busiest international shipping routes on the continent. There are

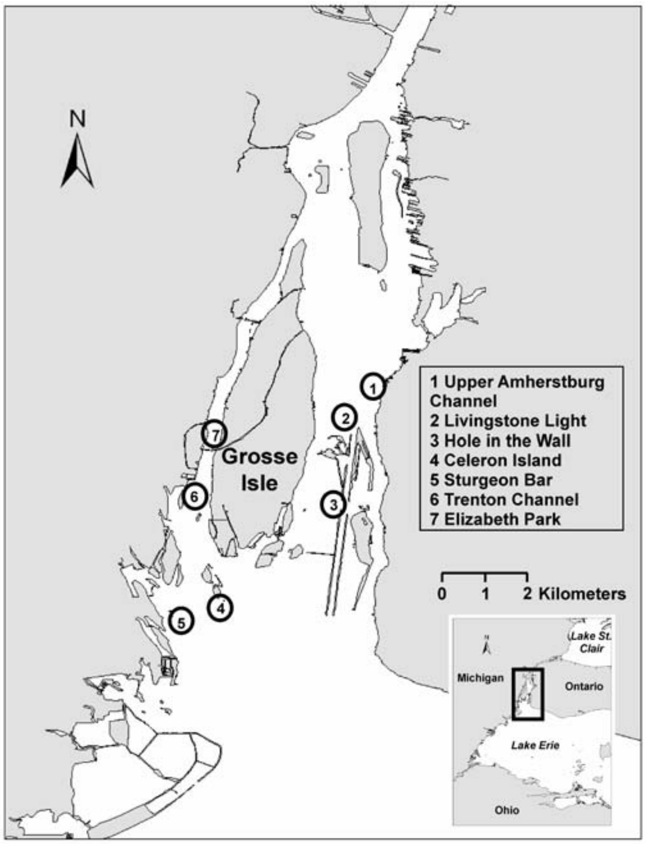

FIG. 3. Egg and gillnet sample sites in the lower Detroit River sampled during November and December 2005.

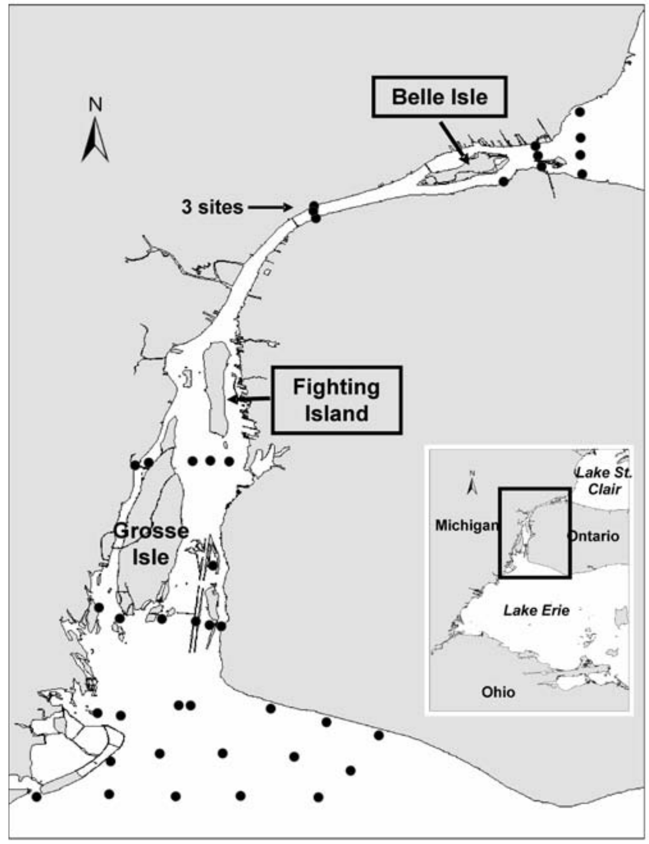

FIG. 4. Larval fish sampling stations in the Detroit River and western Lake Erie, spring 2006.

two federal Wildlife Refuges (Detroit River International and Ottawa) offset by an Area of Concern where water use is impaired by the loss of fish and wildlife habitat. Remediation, protection, and harvest of native fish species in these waters is further complicated by the ecological impacts of numerous invasive exotic species (sea lamprey, dreissenid mussels, round goby (*Neogobius melanostomus*), and white perch (*Morone americana*)).

We looked for evidence of lake whitefish spawning in the lower Detroit River using two approaches; gillnetting for spawning adults and sampling for deposited eggs on the river bottom using a diaphragm pump. Sites for gillnet sampling included previously known spawning areas (Goodyear *et al.* 1982) and areas selected by the investigators following recommendations by regional fishery scientists and collaborating partners who work on the river. All adult and egg sampling sites were located within the Detroit River International Wildlife Refuge. Gillnet sites included the Upper Amherstburg Channel, Hole in the Wall, Celeron Island, East Livingstone Channel, lower Trenton Channel, and Sturgeon Bar (Fig. 3). Sample sites were located using a global positioning system. Effort was not consistent between sites because two types of gillnet were used. A 182.9 m × 2.4 m net was composed of twelve 15.24 m panels of the following bar mesh sizes listed in the order rigged: 3.81 cm, 15.24 cm, 17.78 cm, 10.16 cm, 16.51 cm, 6.35 cm, 12.70 cm, 5.08 cm, 7.62 cm, 8.89 cm, 13.97 cm, and 11.43 cm. We also used standard experimental monofilament gill nets consisting of a single 8 m × 2 m panel of each of the following bar mesh sizes: 2.54 cm, 5.08 cm, 7.62 cm, 10.16 cm, and 12.70 cm. Gillnets were deployed in late afternoon and lifted by 1000 hours the following morning. Gillnets were set once per week beginning 10 November through 4 December 2005 and terminated when the river was no longer navigable due to ice flows. Nets were fished on bottom and set parallel with the current adjacent to suspected spawning reefs. Fish collected in gillnets were either measured and released or stored on ice and processed in the laboratory. At the laboratory, lake whitefish were measured (mm TL) and weighed (g). Both sagittal otoliths and samples of scales were removed for age estimation. Age determination followed standard USGS Great Lakes Science Center age estimation protocol for thin sectioning and mounting otoliths (USGS Great Lakes Science Center, unpublished procedure). Sex, maturity, and reproductive condition were also determined.

We used a 39 kg iron sled (Stauffer 1981) attached to a diaphragm pump at the surface by a flexible hose 5 cm in diameter for egg collections. At each site (Fig. 3), the sled was towed along the bottom at a slow speed (0.5 m/s) or drifted downstream with the river current. Due to differences in river current among sites and the varying direction of the boat during sampling events, sample effort and tow speed varied among sites allowing us to provide only qualitative information on egg abundance. We report the presence or absence of eggs at each site and provide a simple estimate of relative egg abundance (none or low to high) between sites based on numbers of eggs collected and time spent sampling at each site. Eggs and benthic debris (dreissenid mussels and shells, sand, benthic organisms) were deposited from the pump apparatus into a 0.5 m^3 basket lined with 0.5 mm square mesh netting. Eggs were removed with soft forceps when they appeared in the net. Additional samples of lake whitefish eggs were collected incidentally on furnace filter egg mats (Nichols *et al.* 2003) set at Belle Isle as part of a lake sturgeon reproduction study conducted in early spring 2006 (Manny *et al.* 2005).

Eggs were identified based on size, color, oil globule position, and subsequent hatching of eggs in the laboratory and identification of resultant fish larvae. Lake whitefish eggs are approximately 3.0 mm diameter, have a colorless chorion, multiple oil globules, and amber-colored yolk (Auer 1982). To assess over-winter survival of lake whitefish eggs, sites where eggs were collected in December were sampled in early March using the same techniques. Water temperature (°C) was measured at each site with a hand-held alcohol stem thermometer.

Collected eggs were hatched in the laboratory to determine their identity. They were thermally equilibrated and incubated in temperature-controlled well water (2.0 to 3.0°C) flowing at the rate of 0.5-liters/min from a 200 liter head tank through one of two McDonald hatching jars. Each of the jars overflowed into a 19 liter glass holding tank that drained down a standpipe that was tightly covered with plastic window screen of 1 mm porosity. Hatched larvae were washed from the hatching jar into the holding tank where they were captured, preserved in 95% ethanol, and identified.

Beginning in mid-March 2006 when waters became navigable and before lake whitefish eggs had hatched and continuing weekly through mid-June, ichthyoplankton samples were collected at sites in the upper river above Belle Isle, upstream of the Ambassador Bridge, mid river across Hennepin Point on the upstream end of Grosse Isle, the lower river crossing the southern tip of Grosse Isle, and in western Lake Erie near the mouth of the Detroit River (Fig. 4). For these weekly collections, we used a paired bongo sampler weighted with a 22.7 kg oceanographic depressor and fitted with two 60 cm diameter by 3.3 m long nets with mesh sizes of 333 and 500 μm. A flow meter was positioned in the mouth of each net to estimate the volume of water sampled. The bongo sampler was towed into the current at about 2.0 km/h for 6 minutes at each site. This allowed each net to sample about 85 m^3 of water per sample based on flow meter readings. Samples were collected from the upper 2 m of the water column and at 6 m depths where water depth was sufficient. Collected larvae were preserved in the field with 95% ethanol. Larval samples were processed at the laboratory where all fish were removed from samples, identified (Auer 1982), and enumerated. Catch of larval fish was converted to density in terms of numbers of fish/1,000 m^3 of water sampled.

RESULTS

One spermiating male lake whitefish (583 mm TL, 2.0 kg) was collected in a gillnet that was deployed at the upper end of the Amherstburg channel on 18 November 2005. Otolith increment analysis revealed that the fish was 16 years old at the time of capture. The fish appeared to be in good condition having no visible parasites or lamprey wounds, and lacked clinical signs of bacterial kidney disease. Other species collected in gillnets included common carp (*Cyrpinus carpio*) (N = 6), northern pike (*Esox lucious*) (N = 4), gizzard shad (*Dorosoma cepedianum*) (N = 3), and mudpuppy (*Necturus maculosus*) (N = 2).

Viable lake whitefish eggs were collected at three sites in the lower Detroit River on 22 November and 5 December 2005. The most eggs (N = 147)

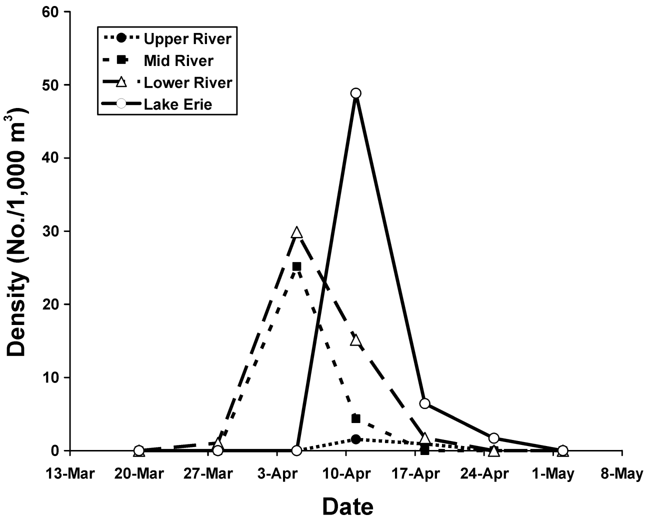

FIG. 5. Density (no./1,000 m^3) of larval lake whitefish collected in the Detroit River and northwestern Lake Erie during spring, 2006.

were collected from Hole in the Wall giving this site the highest relative density of eggs followed by the upper Livingstone Channel (N = 29) site. The fewest lake whitefish eggs (N = 3) were found at site 6 in the lower Trenton channel. Sites where eggs were found were observed to have high flow rates and rock cobble and broken limestone bedrock substrates and depths ranging from 5 to 7 m. No eggs were found at Elizabeth Park, Sturgeon Bar, Celeron Island, or the east side of the upper Amherstburg Channel. Water temperature at egg collections sites in December was 2.5°C. Amphipods and dreissenid mussels were also collected at each site where eggs were found but no other fish eggs were collected in fall. No eggs were found when we resampled these sites in March 2006. The water temperature at egg collection sites in March was 1.0°C. However, viable lake whitefish eggs were collected on egg mats in early April 2006 from a site at the upstream end of Belle Isle when water temperature was 5.2–8.5°C during a survey of walleye and lake sturgeon (*Acipenser fulvescens*) reproduction.

Eggs reared in the laboratory hatched by 25 March 2006. All larvae were identified as lake whitefish. Collections of lake whitefish sac-fry larvae from the river in ichthyoplankton samples provided additional evidence of reproduction occurring in the river. The first larvae appeared in samples collected in the lower river during the week of 27 March when larval density at these sites was less than 1.0 fish/1,000 m^3 (Fig. 5). The water temperature in the river was 4.5°C. Larval lake whitefish densities peaked the following week at both mid (25.1/1,000 m^3) and lower (29.9/1,000 m^3) river sites when water temperatures had reached 5.5°C. Lake whitefish larvae persisted in samples collected from mid and lower river sites through the week of 18 April. Lake whitefish larvae first appeared in samples collected from Lake Erie the week of 11 April (48.8/1,000 m^3) and this was also when the peak density was observed at these sites. Larvae persisted in samples collected in the lake through the week of 25 April. Low numbers of larval lake whitefish were present in samples from the upper river sites only during the weeks of 11 April and 18 April (1.6 and 0.9/1,000 m^3 respectively; Fig. 5). All lake whitefish larvae collected in the river were sac-fry stage and averaged 12.5 mm TL while only a few larger larvae were collected in Lake Erie in mid-April.

DISCUSSION

The discovery of a spawning adult lake whitefish and the collection of viable eggs and larvae are the first scientific evidence of lake whitefish spawning in the Detroit River in nearly 80 years. The Detroit River was once a prolific spawning area for lake whitefish prior to construction of the Livingstone channel in the early 1900s with thousands of pounds of fish and hundreds of thousands of eggs harvested annually during spawning runs (Downing 1923, Milner 1874). Subsequent to this period, few catches of lake whitefish in the river were reported. Hatcher and Nester (1983) reported low numbers of lake whitefish in larval fish samples collected in 1977 and 1978 but these authors thought those fish may have drifted from Lake Huron. Our results provide new information that has assisted in the development of new research on the ecology of spawning and nursery habitat in the Detroit River. Spawning by lake whitefish in the Detroit River may also be evidence of the effectiveness of past environmental remediation polices and activities to improve habitat in the Huron-Erie corridor.

The collection of viable lake whitefish eggs in the lower Detroit River does not necessarily mean the fish spawned at these locations. Eggs could have drifted downstream from spawning areas upstream of the sites where eggs were collected. While it is difficult to estimate how far upstream eggs could have originated, larval lake whitefish were found in high numbers only in the mid and lower river. We believe this information indicates that the majority of lake whitefish spawning areas are located in the middle and lower river. Historic spawning sites for lake whitefish in the Detroit River included shallow areas around Grassy Island and Fighting Island in the middle reaches of the river as well as some sites in the upstream sections of the river near Belle Isle (Goodyear *et al.* 1982, Smith 1917). While much of the historic gravel and rock spawning substrate in the Detroit River has been removed or degraded by sediment (Manny and Kenaga 1991), some suitable spawning substrates still exist near those historic spawning sites (McClain and Manny 2000) and these areas will be the focus of future research on lake whitefish reproduction in the river.

While our adult lake whitefish data do not presently offer an adequate means to accurately estimate the number of fish using the Detroit River to spawn, densities of lake whitefish larvae measured in the river suggest that the number of spawning adults may be large. Peak densities in the Detroit River and nearshore waters of Lake Erie in 2006 were about 30 fish/1,000 m^3 and 48/1,000 m^3, respectively. These densities are considerably higher than densities observed in surveys conducted in 1977 and 1978 when lake whitefish larvae were rare in the Detroit River (0.02 to 0.07/1,000 m^3; Hatcher and Nester 1983). While no other reports of larval lake whitefish abundance in riverine systems could be found, our abundance estimates are in the range of values reported for lake whitefish larvae in lacustrine systems. During larval fish collection conducted in the 1990s, Roseman (1997) found patchy distributions of lake whitefish larvae in western Lake Erie with highest densities (up to 45/1,000 m^3) occurring in mid to late April at nearshore sites along the Ohio shoreline. Densities of larval lake whitefish in Grand Traverse Bay, Lake Michigan ranged from 2.2 to 68.3/1,000 m^3 during surveys conducted in 1983 and 1984 (Freeberg *et al.* 1990).

We believe that the fish found in the Detroit River likely migrated into the river from Lake Erie, as was thought to be the case prior to the collapse of the fishery in the early 1900s (Smith 1917, Milner 1874). Tagging and genetic studies of walleye collected in the system show movement of fish between Lake Erie and Lake St. Clair (Todd and Haas 1993) and more recent data show movement of these fish into Saginaw Bay, Lake Huron (R. C. Haas, Michigan Department of Natural Resources, personal communication), so similar movement patterns of lake whitefish would not be surprising. New tagging and genetic studies of lake whitefish in the Detroit River, Lake Erie, and connecting waters would be valuable to reveal the origins of the Detroit River spawning stock and its relationship to other lake whitefish populations in the Great Lakes. These types of studies could not only yield information on proportional stock contribution to the Lake Erie population, fish movement patterns, and gene flow, but also can provide information about natural and fishing mortality rates of the population. Such research also provides an opportunity to study phenotype-environment interactions and their role in population divergence.

Recovery of a lake whitefish spawning stock in the Detroit River may improve the resilience of the Lake Erie population. The overall population of lake whitefish in Lake Erie is composed of multiple spawning stocks, each using different geographic locations to reproduce. Multiple spawning stocks with restricted gene flow will result in greater overall genetic diversity relative to single populations of the same size (Whitlock and Barton 1997). Because environmental factors that influence lake whitefish embryonic survival, such as ice cover, wind events, and water temperature (Taylor *et al.* 1987), can vary across broad geographic regions (eastern versus western Lake Erie), populations composed of several spawning stocks may have a better chance for annual recruitment if conditions in some locations are unfavorable (Dunson and Travis 1991). In contrast to Lake Erie, environmental conditions in the Detroit River do not vary significantly during winter. Flow remains relatively constant in the Detroit River (Derecki 1984) and wind-induced currents that can remove eggs from incubation areas in lakes (Taylor *et al.* 1987) are likely not a factor. Extreme water temperature fluctuations are a critical factor that might cause reproductive failure of lake whitefish in the river, but these are unlikely to occur given the large volume of water that moves through the river (Derecki 1984).

While scientists do not know exactly what has changed in the Detroit River that now allows successful reproduction by lake whitefish and other fish species, the documented spawning of lake whitefish and other species is likely, in part, a result of 40 years of pollution prevention and control activities in the Detroit/Windsor metropolitan areas and serves as a testament to the effectiveness of past environmental policy and planning to remediate pollution and habitat loss in the system. These findings and the recent discovery of spawning activity by lake sturgeon (Caswell *et al.* 2004) and walleye (Manny *et al.* 2007) in the Detroit River show promise that progress is being made toward achieving fish community objectives directed toward improving fish habitat, restoring native fish stocks, and adding to the system's biodiversity and ecological resilience (MacLennan *et al.* 2003). An obvious threat to successful reproduction by lake whitefish and other species in the Detroit River is spills of oil and chemicals into the St. Clair River and Detroit River that are toxic to fish eggs and larvae. Since the mid-1990s, the number of such spills has decreased (IJC 2006). However, large spills of oil and organic chemicals, such as vinyl chloride, methyl ethyl ketone, and methyl isobutyl ketone, that occurred in the St. Clair-Detroit River Corridor in 2002, 2003, and 2004, represent a toxic threat to fish eggs incubating in the Detroit River and larvae being transported downstream by river discharge in spring.

Construction of new artificial habitats and restoration of former habitat may also be helping native fish restoration efforts. Construction of spawning reefs at Belle Isle in June 2004 has directly benefited lake whitefish. In April-May of 2003 and 2004, no whitefish eggs were collected at the three sites near Belle Isle where the spawning substrates would be placed (Manny 2006). However, in April 2006 we collected eyed lake whitefish eggs from egg mats set on those constructed spawning substrates. Another change that may have benefited the survival of larval lake whitefish since 1995 is the permanent conservation of coastal wetlands that provide nursery habitat for larval fish along the shores of the Detroit River and western Lake Erie, namely Grassy Island, Hennepin Marsh, Stony Island, and Humbug Marsh (Manny 2003, Bull and Craves 2003). Coastal marshes at each of these locations provide suitable nursery habitat for more than 50 fish species (Hintz 2001; Michigan Department of Natural Resources, unpublished data).

As was the case for walleye, recovery of lake whitefish in Lake Erie and the return of spawning stocks to the Detroit River came about due to habitat restoration efforts and a reprieve from exploitation, giving hope that restoration of other species in the basin, such as cisco and deepwater sculpin (*Myoxocephalus thompsonii*), is possible. However, effects of exotic species, exploitation, and reversals in water quality improvements are continued threats that can impede successful recovery of native fishes such as lake whitefish in the Detroit River and Great Lakes basin.

Additional information about the physical and biological characteristics of spawning habitat and the lake whitefish stock that spawns there is needed before any conclusions can be made regarding their status in the Detroit River. Developing an understanding of lake whitefish life history and habitat requirements for the Detroit River and Lake Erie are paramount in developing management strategies that will ensure the continued recovery of sustainable stocks. Further, these types of scientific information are necessary to achieve fish community objectives for sustainable cold water fisheries, fish habitat restoration and protection, and managing a diverse and resilient food web (Ryan *et al.* 2003). Toward this end, further studies are planned that will quantify the timing of lake whitefish spawning runs and characterize populations demographics of spawners, egg deposition and survival, production and transport of larvae, and linkages between spawning areas, egg incubation sites, and larval nursery areas (GLSC 2006).

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